TECHNICAL MANUAL

GENERAL - DESICCANT (ACTIVATED) FOR DYNAMIC AND STATIC DEHUMIDIFICATION AND PACKAGING

(ATOS)

Prepared By: Digital Data Support Group

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INTRODUCTION

1. PURPOSE.

The purpose of this technical order is to provide information and instructions for the use of desiccant.

2. SCOPE.

This publication covers chemically inert dehumidifying agents that prevent corrosion and mildew by absorbing the moisture from the air of an enclosed space.

a. The desiccants discussed are limited to solids only. They are intended for drying applications, although they may be used for removal of other types of gases or vapors from air. The term desiccant refers to dehumidification, which may be either a static (no air in motion) or a dynamic (air in motion) system. Air Force references to publications to desiccant for packaging of parts or equipment will refer primarily to Specification MIL-D-3464, Desiccants, Activated, Bagged, Packaging Use Static Dehumidification. Other publications include Specification MIL-D-3716, Desiccants, Activated, for Dynamic Dehumidification; Specification MIL-C-17605, Charcoal, Activated, Technical Unimpregnated, and Specification MIL-STD-2073-1, Standard Practice for Military Packaging, and Specification ASTM D98-98, Standard Specification for Calcium Chloride.

b. All desiccants described herein should be acquired from the current USAF Management Data List as Federal Stock Class (FSC) 6850 items.

3. DEFINITIONS.

The following definitions will be helpful in understanding instructions contained in this technical order:

Absorption	The taking up of a gas, vapor, or liquid, so that material taken up is physically distributed throughout the body of the absorbent.
Adsorption	The taking up of a gas, vapor, or dissolved material on the surface of a solid, involving a combination of electrical and physical bonding.
Alkali	A term which designates the hydroxides and carbonates of the alkali metals and ammonium radical. The term is applied more generally to any strong base in aqueous solution, such as, a substance which gives a high concentration of hydroxyl ion (OH).
Alumina	This desiccant is usually identified as activated alumina. It is a compound of aluminum and oxygen, chemically inert toward most gases and vapors, is non-toxic and will not soften, swell, or disintegrate when immersed in water. High resistance to shock and abrasion are two important physical characteristics. Alumina is available in the AF Management Data List, and is identified by several stock numbers in FSC 6850.
Anhydrous	Pertaining to a salt which has no water of hydration present in the crystalline structure.
Calcium Sulfate	Is an all-purpose desiccant and is available under National Stock Number (NSN) 6810-00-242-4066 and P/N OD-210. It is neutral, stable, chemically-inactive toward most reagents other than water, is non-poisonous, non-corrosive, and regenerative. It is not highly resistant to shock and abrasions, but has high drying rate with a limited capacity of 10 – 14% moisture.
Clay	A term for a great variety of aluminum silicate soils of various compositions and degrees of purity. They are plastic when wet, and harden when heated (fired). Clay desiccant are produced under MIL-D-3464, and are available in FSC 6850.
Corrosion	Conversion of metals into oxides, carbonates, or other compounds due to action of air, water, or other chemicals contained in the environment.
Dehumidification	The removal of moisture (water vapor) from the air, also sometimes extended to analogous processes of removing a vapor from a gas mixture.
Deliquescent	Able to take up water vapor until dissolved.
Desiccant	A substance used to absorb or absorb water vapor within a container; a dehydrating agent.
Humidity, Absolute	The actual weight of water vapor contained in a unit weight of air.

Humidity, Relative	The percentage relation that the actual amount of water vapor present in a given volume of air at a definite temperature bears to the maximum amount of water vapor that would be present if the air were saturated with water vapor at that temperature.
Molecular Sieves (Aluminum Silicates)	This is a high performance desiccant, made synthetically, with a high degree of uniformity. It is a high drying rate desiccant with a medium capacity of 20 – 24% moisture. It is available in powder, pellets, and bead forms, with the moisture-indicating form available as impregnated beads. Molecular sieves can be used for selective gas absorption and can perform virtually all the adsorption duties now assigned to other desiccants. They differentiate on the basis of molecular size and configuration, and are highly resistant to shock and abrasion. They are insoluble in all solvents, permitting great process design latitude. Several molecular sieves are stock-numbered and are available in the AF Management Data List, FSC 6850.
Molecule	The smallest unit of a compound which has the same chemical properties of the compound. Upon decomposition, molecules break down into simpler molecules or atoms or both.
Saturation	The state of a solution when it holds the maximum equilibrium quantity of dissolved matter at a given temperature.
Silica Gel	This is the highest capacity adsorbent available today, being prepared from sodium silicate and sulfuric acid, and has a fair degree of uniformity. It is a high capacity desiccant with a medium adsorption rate. It is totally inert and compatible with all materials except strong alkalies and hydrofluoric acid. Due to many micro size pores, it can adsorb over 40% of its weight of water. It can act as a selective adsorbent for different gases and polar liquids. Silica gel is a hard, rugged material producing little dust. It is acquired from AF Supply Lists as indicating and non-indicating type, and is available in granular or powder forms, FSC 6850.

CHAPTER 1
INDICATING AND NON-INDICATING DESICCANT

1.1 INDICATING DESICCANT.

The INDICATING type of desiccant is impregnated with an indicator for the purpose of providing a visual approximation of the degree of saturation of the desiccant. This desiccant shall be used in indicator plugs, indicator cards, in certain aircraft applications, or whenever an approximate indication of humidity is desired. Parts and materials to be protected by use of desiccant (indicating type) will be specified in technical instructions or specifications covering the items to be protected. Indicating desiccant is not intended for use in bulk form. It is used to a limited extent to protect instruments, tools, parts, raw materials, etc., against damage resulting from excess moisture by inclusion in moisture-proof containers or storage cabinets with the part to be protected. The non-indicating type shall be used to supplement the indicating type desiccant in storage and shipment of instruments, bearings, etc. In all cases where the non-indicating type is used in conjunction with the indicating in closed containers, care will be exercised to prevent prior exposure to outside moisture of both types. Sufficient time must elapse before equilibrium is established between the desiccant and the atmosphere within the enclosed space. When equilibrium is established, the indicating type will show the desired protection is achieved by the blue color of the indicating desiccant. Change desiccant when blue color turns buff or pink.

1.2 NON-INDICATING DESICCANT.

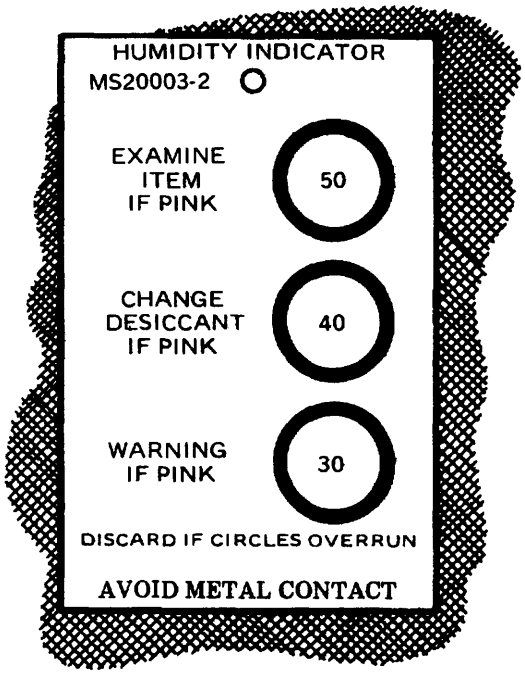
The NON-INDICATING type desiccant is furnished in desiccant units; a desiccant unit is that quantity of desiccant, as received, which will adsorb at equilibrium with air at 25°C (77°F) at least 6.00 grams at 40% relative humidity. The non-indicating type is used in any application where the indicating type is not required, especially inside barrier material, flexible, Specification MIL-B-131 bags in conjunction with indicator cards for protection of engines by removal of moisture in storage or shipment. The indicator cards are used to indicate the relative humidity by color change.

1.3 INDICATOR CARDS.

The indicator cards have circles impregnated with cobalt chloride, which change from blue to pink or vice versa at the percent of the relative humidities they are exposed to, as stated on the cards circles, in any container. Examples of the two cards are shown in Figure 1-1 for MS20003-2 and Figure 1-2 for MS20003-3.

1.4 AVOID UNNECESSARY EXPOSURE TO MOISTURE.

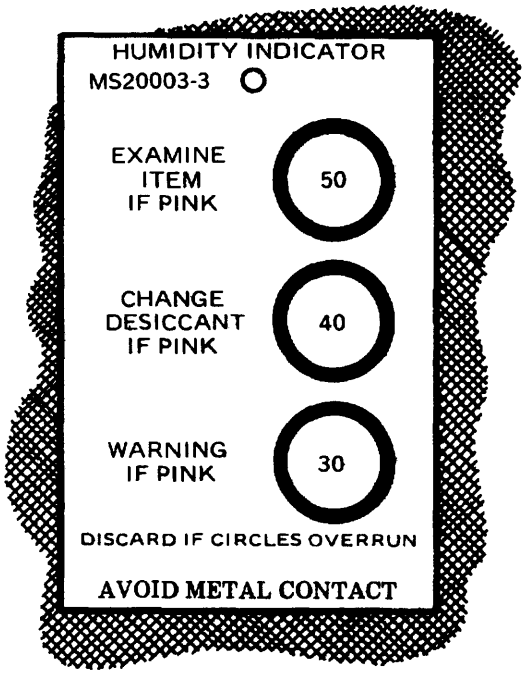
Care must be exercised that the non-indicating type desiccant is not subjected to premature moisture exposure and that the indicator cards are protected; otherwise, the indicator cards will not show the amount of protection against moisture in the package until a sufficient period of time has elapsed for the two types to reach equilibrium. All serviceable bulk desiccant will be kept in air tight containers and the entire contents of a package shall be used as soon as possible after opening.



MS PART NO.	SPOT	RELATIVE HUMIDITY ± 5%
MS20003-2	TOP	50%
	MIDDLE	40%
	BOTTOM	30%

NSN 6685-00-752-8240

Figure 1-1. Indicator Card (MS20003-2)



MS PART NO.	SPOT	RELATIVE HUMIDITY ± 5%
MS20003-3	TOP	50%
	MIDDLE	40%
	BOTTOM	30%

Figure 1-2. Indicator Card (MS20003-3)

CHAPTER 2
MODES OF DEHUMIDIFICATION

2.1 STATIC AND DYNAMIC.

There are two basic modes for controlling humidity: static dehumidification and dynamic dehumidification. In determining which type to use in a particular instance, each must be evaluated as to its advantages, disadvantages, and comparative economical value in the special area of preservation or application involved.

a. STATIC DEHUMIDIFICATION: Desiccant used for static dehumidification must meet the requirements of Military Specification MIL-D-3464, Types I and II. Desiccant furnished under and in compliance with MIL-D-3464 are supplied in bags, with the amount of desiccant in a bag dependent on the specific application. Because the moisture absorption ability of the various desiccant differs, the requirements of MIL-D-3464 are based on desiccant units. A unit weight shall not exceed 50.0 grams. A desiccant unit is that quantity of desiccant, as received, which will adsorb at equilibrium with air at 25°C (77°F) at least 3.00 grams of water vapor at 20% relative humidity and at least 6.00 grams at 40% relative humidity.

b. DYNAMIC DEHUMIDIFICATION: The desiccant for dynamic dehumidification is procured under MIL-D-3716. This specification covers desiccants intended for the removal of moisture from air, other gases, and liquids, and for the approximate indication of the relative humidity of an enclosed space. MIL-D-3716, Types I and II desiccants are intended for use in mechanical dehumidification machines. Type III desiccant is intended for use in indicator cards or humiplugs, when an approximate indication of the relative humidity in the surrounding atmosphere is desired.

2.2 DESICCANT IN CABINETS AND CONTAINERS.

Desiccants in bags conforming to Specification MIL-D-3464 will be used when the materials to be protected are stored in containers or cabinets. In order to obtain maximum efficiency from the desiccant, a number of bags containing small portions of the total quantity required to protect material in a specific container or cabinet will be equally spaced throughout the cabinet. This will insure circulation of air through the desiccant with a maximum of surface exposure.

2.3 DESICCANT IN DRYING ROOMS.

If desiccant is to be used in large cabinets or rooms used for storing materials, these cabinets should contain trays fabricated locally, the bottom of which should consist of 20-mesh screen to allow air to circulate freely through the desiccant. Indicator cards on one tray of the indicating type desiccant should be placed where readily visible in order to determine the protection being afforded within the cabinet. The length of time the desiccant will remain effective is determined by the size of the container, the upper limit of relative humidity allowable for the particular item, the impermeability of the moisture barrier or walls of the cabinet, the frequency of opening of the cabinet, and the relative humidity of ambient air.

2.4 ACCEPTABLE CONTAINER MATERIAL.

CAUTION

All desiccant, after becoming saturated with water, may become highly corrosive on certain metals. All desiccant spilled on metal surfaces shall be removed immediately to prevent corrosion of metals.

Articles packaged for storage or shipment which require dehydration for adequate protection will be placed in container of metal, plastic film, metal foil, or other material which is relatively impervious to moisture.

CHAPTER 3
GENERAL CRITERIA FOR APPLICATIONS

3.1 ALUMINA.

Dry activated alumina can be used to dry the following gases: air, nitrogen, hydrogen, oxygen, carbon dioxide, chlorine, sulfur dioxide, ethylene, butane, freon, and natural gas. Air Force applications for activated alumina include the use of alumina for dynamic dehumidification of air and other gases wherever removal of objectionable quantities of water is desirable. Alumina (chromatography grade) is also used extensively in laboratory applications such as column and gas-liquid chromatography.

3.2 CALCIUM SULFATE.

Calcium sulfate is an all-purpose desiccant, manufactured by complete dehydration of gypsum in an electric furnace at 300°C (572°F). It is then crushed and sized.

a. Calcium sulfate (O-D-210) is available as powder and granular forms in AF Supply Lists, FSC 6850. It is also available as an indicating type when impregnated with cobaltous chloride **($CoCl_2$).**

b. Calcium sulfate is neutral, stable, chemically inactive toward reagents other than water, insoluble in most organic solvents, nonpoisonous, and regenerative at 204° – 218°C (399.2° – 424.4°F). It will absorb 6.6% of its weight of water as the hemihydrate **$CaSO_4.1/2\ H_2O$** and can also exist as the dihydrate **$CaSO_4.2\ H_2O$.** Capillary and chemical adsorption can bring the total moisture content to 10 – 14% in saturated air.

c. The drying rate of calcium sulfate compares favorably with the best desiccants, a dew point of –62°C (–79.6°F) can be obtained. It maintains its drying efficiency until nearly exhausted even at 65°C (149°F). It is an excellent drying agent for organic liquids and vapors, where the boiling points are below 104°C (219.2°F). The total heat of adsorption of calcium sulfate is considerably higher than silica or alumina gel and likewise the heat of activation is higher. Heating above 302°C (575.6°F) reduces its activity.

d. Air Force applications include the use of calcium sulfate in dynamic dehumidification of air and gases. Calcium sulfate is also used in the static dehumidification (drying) of organic reagents, organic liquids, refrigerants, and packaging methods as indicated in MIL-STD-2073-1 and MIL-D-3464. Calcium sulfate is widely used in laboratory applications as the desiccant in desiccators.

3.3 CLAYS.

Clay desiccants are usually porous, non-corrosive mixtures, quite often a form of marine origin soils. They are the least expensive of all desiccants and consequently they are used to a large extent in Air Force static dehumidification applications. Clay desiccants are most commonly used to meet desiccant requirements as stated in MIL-D-3464 and MIL-STD-2073-1. They are obtained from various locations, some being as follows:

a. Attapulgite (Mg Al) **$_5Si_8O_{22}\ (OH)_4.4H_2O$** – Florida and Georgia

b. Montmorillonite **$Al_2O_34SiO_2.H_2O$** – Arizona

c. Fuller's Earth **$Al_2O_3SiO_2.H_2O$** – Florida, Georgia, and Texas

3.4 MOLECULAR SIEVES.

Molecular sieves are a group of synthetically-made adsorbent desiccants. They are crystalline, hydrated metal aluminosilicates having a basic formula consisting of a metal, aluminum oxide, silicon oxide, and varying amounts of water of hydration.

a. They can adsorb differentially because of the various sizes or pores within the crystalline structure of the respective types of metal aluminosilicate molecules.

(1) For example, the Type 3A molecular sieve, **K_{12}** (AlO_2)**12** (SiO_2)**12**.X **H_2O** has pores within its molecular structure which will allow the adsorption of molecules with critical diameters up to 3 angstroms.

(2) Type 4A molecular sieves, **Na_{12}** (AlO_2)**12** (SiO_2).X **H_2O** can adsorb molecules with critical diameters up to 4 angstroms.

(3) Type 5A molecular sieves, $Ca_{4.5}$ **Na_3** (AlO_2)**12** (SiO_2)**12.X H_2O** can adsorb molecules up to 5 angstroms critical diameter.

(4) Type 13X molecular sieve, **Na_{86}** (AlO_2)**86** (SiO_2)**106.X H_2O,** can adsorb molecules with critical diameters up to 10 angstroms. Type 13X can also adsorb all the smaller molecules which are adsorbed on Types 3A, 4A, and 5A molecular sieves.

b. Molecular sieves are intended for use in both static and dynamic dehumidification. With large surface

area and pore volume, molecular sieves can perform virtually all the adsorption functions of other absorbents, and can also differentiate on the basis of molecular size and configuration. Molecular sieves dry gas streams effectively at high temperatures, and will adsorb five times as much water as other types of absorbents at low partial pressure or relative humidity. Molecular sieves retain absorbates by strong physical forces rather than by chemical means which allows complete reversibility.

c. Molecular sieves have a wider range of operating conditions than those tolerated by any other adsorbent, permitting greater process design latitude. They are also suitable for drying, catalytic uses, purifying, and separating a wider variety of feeds than any other adsorbent or absorbent. Molecular sieves are available as indicating type containing **$CoCl_2$, $NiCl_2$** and binders, which change color from blue to pinkish gray when the air approaches 10% relative humidity, indicating that the sieve has adsorbed either 50 or 75% of its available water capacity. Molecular sieves are listed in the USAF Management Data List.

d. Air Force applications include use of molecular sieves in static dehumidification, e.g., storage of packaged parts and material, and humidity control within many vital electronic components of aircraft and airborne weapons systems; and in dynamic dehumidification e.g., removal of **H_2O** and **CO_2** in liquid oxygen production. Many molecular sieve desiccants have been introduced into the Air Force inventory as manufacturers' part number items; however, Air Force users shall try to use fewer part number items and shall rely instead upon standardized stock-numbered items whenever such a choice is possible.

3.5 SILICA GEL.

Silica gel will differentiate between certain molecules acting as a selective adsorbent for highly polar liquids as methyl, ethyl, propyl, and higher alcohols. Its adsorbability decreases in decreasing polarity. Relative order of adsorbability for several compounds is as follows: water, alcohols, aromatics, di-olefins, olefins, paraffins, hydrochloric acid, gasoline-range hydrocarbons, carbon dioxide, chlorine, sulfur, and nitrogen compounds. Silica gel adsorbs water vapor preferentially in the presence of other vapors.

a. Silica gel is a non-conductor of electricity and can be impregnated with cobalt chloride to produce a moisture indicating material. The color change at given relative humidity is as follows:

0 to 20 r. h. – blue
20 to 40 r. h. – lavender
40 to 60 r. h. – buff pink
60 to 100 r. h. – pale pink

b. Air Force applications for silica gel are numerous. Silica gel is used as a static dehumidifier for packaging, in indicating humiplugs, for insulating and dehumidifying sealed glass window units in aircraft and elsewhere, and as a desiccant inside electrical cables, particularly at the site of cable splicing. It is used in dynamic dehumidification applications for drying air, gases, and liquids. When used in dynamic dehumidification equipment, it can produce effluent relative humidities lower than 1%. Silica gel is used in Air Force laboratory applications as a chromatographic column packing.

c. Silica gel desiccant in the form of spherical beads with an average diameter of 0.138 to 0.141 inch is intended for use in adsorbing oil vapors generated during the manufacture of liquid oxygen at a process flow temperature of −153°C (243.4°F). NSN 6850-00-823-8143 or equivalent is the recommended desiccant for this application.

3.6 CALCIUM CHLORIDE.

Calcium chloride forms mono, di, tetra, and hexahydrates. It is prepared as a by-product in the ammonia-soda process and from natural, salt brines. The anhydrous form will dehydrate organic liquids and gases. The flake form is essentially the dehydrate **$CaCl_2.2\ H_2O$.** It is freely soluble in water and alcohol having a purity range of 94 – 97%, calcium hydroxide being the chief impurity. The anhydrous form calcium chloride is very hygroscopic and liberates much heat. It is deliquescent since it will dissolve completely in its absorbed moisture, if the vapor pressure of the air equals or exceeds that of the saturated solution at the prevailing temperature. It will liberate water when the humidity decreases.

3.7 IMPREGNATED CARBON (CHARCOAL).

Impregnated carbon is a very adaptable and widely used adsorbent. It is capable of adsorbing large amounts of water, but organic vapors will tend to displace the water adsorbed.

a. Impregnated carbon has an adsorbent capacity for a wide range of molecular sizes, due to the millions of small boles. By proper selection of charcoal type, it is possible to fractionate different molecules. It will remove practically any type of impurity from air, gases, and liquid mixtures.

b. The adsorption that takes place is of a physical nature, based on molecular forces. It can be reactivated at **93**° – **121**°**C** (199.4° – 249.8°F) and can be blended with other inorganic desiccating agents, as calcium chloride, to give desiccant adsorbing water in the vicinity of 20% by weight.

c. Air Force applications of impregnated carbon include the use of carbon in safety respirators to remove organic vapors, and as a water and hydrocarbon remover in liquid oxygen production.

3.8 LITHIUM HYDROXIDE.

CAUTION

All desiccant, after becoming saturated with water, may become highly corrosive on certain metals. All desiccant spilled on metal surfaces shall be removed immediately to prevent corrosion of metals.

Lithium hydroxide, also known as lithium hydrate is prepared by electrolysis of lithium chloride. It exists as a white crystalline powder. It will adsorb moisture and carbon dioxide from the air and it is deliquescent.

CHAPTER 4
METHODS OF APPLICATION

4.1 STATIC DEHUMIDIFICATION.

Static dehumidification is accomplished by placing a desiccant (MIL-D-3464) in the space to be dehumidified. The desiccant absorbs water from the surrounding atmosphere. Because the desiccant has a limit in its ability to take water from atmosphere, moisture laden air or free water must be prevented from reaching the area being dried by the drying agent. Existing barrier materials differ in their water vapor transmission rates and in their ability to maintain a desired moisture level in a package over a period of time. For military packaging purposes, these barrier materials must have a water vapor transmission rate of no more than 1.0 milligrams per 100 square inches (620.0 square cm) of surface area in 24 hours. See Method 50 in MIL-STD-2073-1, Standard Practice for Military Packaging. The minimum quantity of desiccant for use per package shall be determined in accordance with the following formulas as applicable.

a. FORMULA I. (See Table 4-1) To find units of desiccant for use within flexible water-proof barriers other than rigid metal containers:

The amount of desiccant required depends upon the surface area of the flexible packaging material and the weight of interior cushioning used within the barrier. The area opposite each unit quantity listed represents the maximum barrier area that can be protected.

EXAMPLE: Item enclosed in barrier bag having dimension of 4 by 10 inches. Surface area equals 4 x 10 x 2 sides –80 square inches per Formula I, a 1-unit bag of desiccant is required. If the area of the flexible barrier exceeds Table 4-1, calculate as follows:

Units of desiccant = C times (x) A plus XD

C = 0.011 when barrier area is in square inches

C = 1.6 when barrier area is in square feet

A = area of barrier in square inches of feet

XD = see Table 4-2 and Formula II below

NOTE

Use 1 unit of desiccant for each: 90 square inches of barrier, 0.6 square feet, or 558 sq cm of barrier.

b. FORMULA II. (See Table 4-2) To find units of desiccant for use within sealed, rigid metal containers.

Also Formula II may be used to determine units of desiccant required for sealed rigid containers (other than metal) when the sealed barrier provides a water vapor transmission rate not exceeding 0.001 grams per 24 hours per 100 square inches (620 sq cm) as established by government specification or when tested per Method 252 – Federal Test Method Standard No. 101. The amount of desiccant required depends upon the volume within the rigid barrier. The volume opposite each quantity of desiccant listed represents the maximum volume that can be protected.

EXAMPLE: Item enclosed in steel drum 24 inches in diameter and 50 inches high. Volume of drum is computed: 3.14 x $\mathbf{12^2}$ **x** 50 = 22,608 cubic inches. From Formula II, 16 units of desiccant are required. If the volume exceeds Table 4-2, calculate as follows:

Units of desiccant = K times (x) V plus XD

K = 0.161 when volume is in gallons

K = 0.0007 when volume is in cubic inches

K = 1.2 when volume is in cubic feet

V = volume of container

XD = see Table 4-3 and Formula III below

NOTE

Use 1 unit of desiccant for each: 23.5 liters, 6.2 gallons, 0.83 cubic foot of volume, or 1432 cubic inches of volume.

c. FORMULA III. (See Table 4-3) Dunnage material for interior cushioning, blocking, or bracing:

The amount of desiccant required to offset the dunnage within a package depends upon the type and weight of cushioning used.

EXAMPLE: Item packed utilizes 907 gm of foam cushioning = 1 unit of desiccant per Formula III.

ADD THIS AMOUNT TO THE QUANTITY REQUIRED PER Table 4-1 OR Table 4-2.

The basis for Formula III is:

Units of desiccant = XD

D = weight of dunnage inside package

X = 8 for hair, felt, cellulosic material, wood, or other material categorized below

X = 6 for bound fibers

X = 2 for glass fibers

X = 0.5 for synthetic foams or rubber

4.2 INDICATORS.

a. Humidity indicators are included as a check on the condition of the dehumidified package.

Indicators used in military packaging include those conforming to MIL-I-8835 and MIL-I-26860. The humidity indicating cards conforming to MIL-I-8835 are intended for use Method 50 of MIL-STD-2073-1, in which it is necessary to determine that the desiccant within a package is sufficiently active to maintain a relative humidity below that at which corrosion might occur. The card may also be used in any application in which a knowledge of the approximate relative humidity within an enclosed space is desired. The humidity indicating plugs conforming to MIL-I-26860 are externally mounted color change humidity indicators for determining relative humidity within rigid containers and flexible moisture vapor-proof envelopes or bags. Indicators can be manufactured to MS20003, MS16770 and MS16771.

4.3 DYNAMIC DEHUMIDIFICATION MACHINES.

Dynamic dehumidification involves either the continuous or intermittent processing of the air volume in an enclosure in such a way that the relative humidity is maintained consistent at a desired acceptable level. This is accomplished with various kinds of air circulating machinery. These machines employ one or more desiccant beds and the necessary air ducts, filters, fans, and heaters. The air is first filtered to remove dirt and dust, then drawn over the desiccant bed where moisture is removed, and finally returned to the space being dehumidified. If only one desiccant bed is used, it must be replaced periodically. If two beds are used, one can be replaced while the other is in operation.

4.4 DESICCANTS USED IN LOX GENERATORS.

The desiccants used in LOX generators will include various combinations of, and numerous spatial configurations of molecular sieve material; activated silica gel; silica gel beads; activated carbon (charcoal); activated alumina, and activated tabular alumina. The different combinations and configurations will be identified in the specific Technical Manual used to perform maintenance on the different LOX generators.

4.5 TECHNICAL MANUALS FOR OPERATING LOX GENERATORS.

Specific technical guidance for using desiccants in LOX generators must be acquired: from the applicable technical manuals in the 36G1 T.O. series which includes, but is not limited to, the following:

a. T.O. 36G1-2-12-1, OPN and MAINT INSTR – Oxygen and Nitrogen Generating and Charging Plant, 1.5 Ton/Day, Model ASU1.5-6000-540RPSA, P/N 790380-001 Pacific Consolidated

b. T.O. 36G1-2-13-1, OPN and MAINT INSTR – LOX/LIN Generating Plant, 1 Ton/Day, Trailer Mounted, P/N 3206101-1, Cosmodyne

c. T.O. 36G1-2-14-1, OPN and MAINT INSTR – LOX/LIN Generating Plant, 5 Ton/Day, P/N 9329011-3, AVEL

d. T.O. 36G1-2-15-1, OPN and MAINT INSTR – Liquid Oxygen/Nitrogen Servicing Plant, 5 Ton/Day, P/N 791722-001, Pacific Consolidated

4.6 LOX GENERATOR DESICCANT PROBLEMS.

Specific questions and problems concerning use of desiccants in LOX generators should be addressed to AFTT at, DET 3, WR-ALC/AFTT 2430 C, Street, Building 70, Area B, WPAFB, OH 45433-7632..

Table 4-1. Formula I

Area in Square Inches	Area in Square Feet	Area in Square Centimeters	Units Desiccant Required
15	0.1	93.0	1/6
30	0.2	186.0	1/3
45	0.3	279.0	1/2
90	0.6	558.0	1
150	1.0	930.0	2
360	2.5	2323.0	4
720	5.0	4646.0	8
1,440	10.0	9300.0	16
7,200	50.0	46460.0	80

Table 4-2. Formula II

Volume in gallons	Volume in Cubic Feet	Volume in Cubic Inches	Volume in Liters	Units Desiccant Required
1.1	0.14	254	4.16	1/6
2.1	0.28	485	7.95	1/3
3.2	0.42	739	12.11	1/2
6.2	0.83	1432	23.47	1
12.5	1.67	2888	47.32	2
25.0	3.33	5775	94.63	4
50.0	6.67	11550	189.27	8
99.7	13.33	23031	377.40	16
498.5	66.67	115153	1887.00	80

Table 4-3. Formula III

Hair, Felt and Wood	Bound Fibers	Glass Fibers	Synthetic Foam & Rubber	Units Desiccants Required
9.5 gm	12.8 gms	36.86 gm	150.26 gm	1/6
18.5 gm	25.5 gms	76.55 gm	303.35 gm	1/3
28.35 gm	39.69 gm	113.40 gm	453.60 gm	1/2
56.70 gm	76.55 gm	226.80 gm	907.20 gm	1
113.40 gm	150.26 gm	453.60 gm	1.814 kg	2
226.80 gm	303.35 gm	907.20 gm	3.629 kg	4
453.60 gm	589.68 gm	1.814 kg	7.258 kg	8
907.20 gm	1.225 kg	3.628 kg	14.515 kg	16
4.536 kg	6.033 kg	18.144 kg	72.576 kg	80

CHAPTER 5
INSPECTION OF CONTAINERS

5.1 GENERAL INSTRUCTIONS.

Various technical orders covering equipment specify the frequency of inspection of the package and when indicator cards are used, the relative humidity can be judged at a glance. If no instructions are given, the containers that are known not to be entirely impervious to moisture permeation will be inspected at periods not greater than 6 months. Inspections of such packages should take place when relative humidity of the air in the room is abnormally low. A dry heated room on a cold, clear day will give this protection. Desiccant in air tight containers such as metal and glass need be inspected only when there is reason to believe that the container is no longer air tight; however, visual inspection of the containers will be made at 6 month periods or more often whenever air leakage is suspected.

CHAPTER 6
DISPOSITION OF SPENT DESICCANT

6.1 REACTIVATION.

Reactivation of used desiccant is generally not practicable for three reasons:

a. The oil and oil vapors adsorbed by desiccant do not readily leave the desiccant at reactivating temperatures, which the desiccant will stand without decomposition; therefore, the cells or pores of the desiccant are coated with the oily material and the desiccant loses its original capacity to adsorb moisture.

b. The quantity of oil and organic vapors which are removed from the desiccant in the reactivation process frequently form a flammable mixture with air, as organic vapors are flammable in very low concentration with air.

c. Closely controlled procedures are necessary for complete reactivation without burning, or decomposing the desiccant. The color change of impregnated desiccant is frequently and erroneously used as, an indication of completeness of changes to blue, while the interior remains saturated. Equilibrium is reached only after days of SOAKING in a constant humidity. Consequently, desiccant will not be reactivated, but will continue to be disposed of locally through local procedures, since it has no economical value to the Air Force as a desiccant.

6.2 SPENT DESICCANTS.

Used desiccant contaminated with hazardous waste will be turned into DRMO for disposal as solid waste. Contact your Medical Service Environmental Engineering Services for current solid waste label with FSN and contaminates of the product. Packaging must be in accordance with DOT instructions. Packaging will be dictated by the hazard of the contaminate.

CHAPTER 7
TEST PROCEDURE FOR DETERMINING THE UNIT ADSORPTION CAPACITY OF MIL-D-3464 DESICCANT

7.1 APPARATUS.

The general arrangement of the apparatus shall be as shown on Figure 7-1. The fitting comprising the inlet, outlet, and petticoat bubbler for each saturator bottle shall have a ground glass stopper to fit the bottle. The saturator bottles and bubbler shall be designed so that with 1 liter of solution in the bottle, the upper holes of the bubbler shall be no more than 3 inches, nor less than 1 inch below the surface of the liquid. Each of the six saturator bottles shall be filled with 1 liter of identical sulfuric acid solutions to give the desired relative humidity at 77°F (25°C) in accordance with Table 7-1.

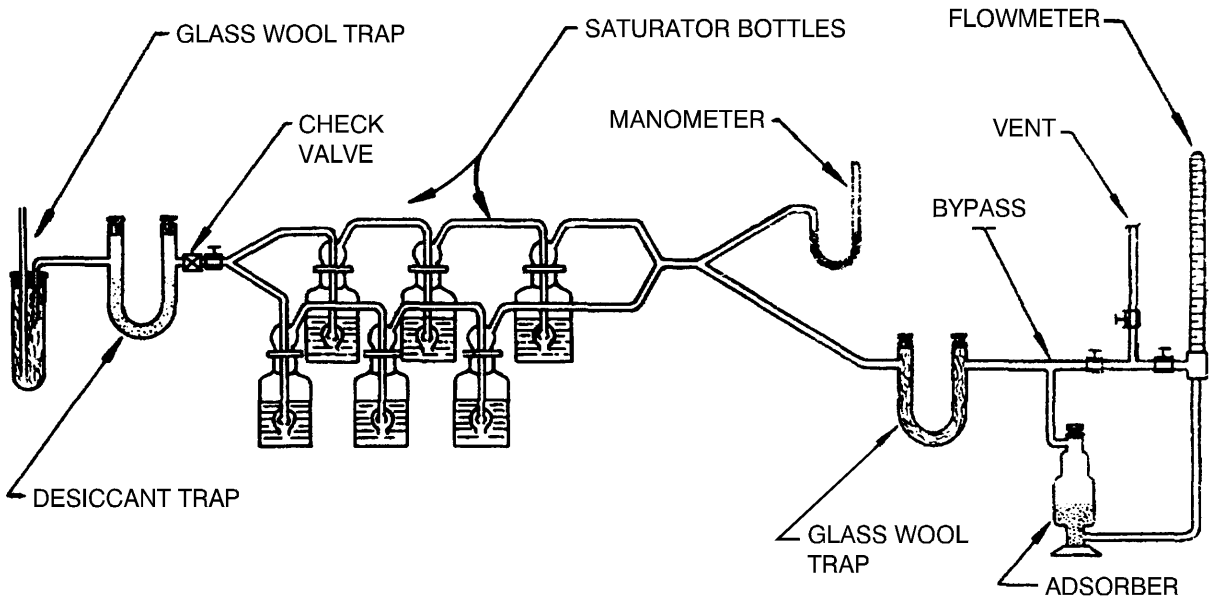


Figure 7-1. Required Apparatus

Table 7-1. Relative Humidity Solutions

Solution	Percent by Weight	R. H. Percent at 25°C	Sp. Gr. 20°/4°C	Sp. Gr. 77°/60°F
H_2SO_4	64.6	10	1.5499	1.5426
H_2SO_4	58.2	20	1.4789	1.4754
H_2SO_4	47.8	40	1.3739	1.3715
H_2SO_4	38.4	60	1.2889	1.2859
H_2SO_4	26.2	80	1.1894	1.1853

NOTE

Specific gravity measurements should be made at either indicated temperature using a precision hydrometer with smallest subdivision 0.0005 unit.

7.2 SAMPLE BOTTLE.

The sample-containing bottle shall be a Nesbitt, Fleming, or other standard form of adsorption bulb. The bulb shall be provided with a suitable closure to prevent diffusion. The room in which the tests are being run should be controlled to 77°F ± **4°F (25°C** ± 2°C). It is essential that the temperature variation within the saturator bottles, the inlet air, and the sample-containing bottle during any one run shall vary not more than ± **2°F** (1°C). A desiccant trap filled with activated desiccant under test shall be placed in front of the saturated bottles to pick up any adsorptive impurities in the inlet air.

7.3 PROCEDURES.

A 6 to 10 gram sample of the desiccant shall be weighed to the nearest milligram in the tared adsorption bulb. Extreme care shall be exercised to insure that the material is exposed to the air for a minimum time. The adsorption bulb shall then be connected to the apparatus and the air flow adjusted to 4 ± 0.5 liters per minute with the bypass closed. If the manometer indicates the pressure in the last bottle to be greater than 1 inch mercury, the bleed-off line should then be cracked open until the manometer indicates less than 1 inch and that point maintained for the balance of the run. When using the bypass, an occasional check shall be made of the amount of air passing through the adsorption bulb by diverting the bypass air from the flow meter at atmosphere through the TEE connection. The flow meter reading will then indicate the actual air flow through the adsorption bulb. Periodically the adsorption bulb shall be removed from the train, the stopcocks closed, and the bulb weighed. This process shall be repeated until two successive weighings, approximately 1 hour apart, show a weight variation not exceeding 5 milligrams (0.1 percent for MIL-D-3716 desiccant); however, the test shall be considered complete if at any time the minimum specified values are attained. It will generally be found that the weight will rise to a maximum and the decrease slightly before approaching a constant value.

7.4 FORMULA FOR CALCULATION.

The adsorption capacity of the desiccant shall be determined by the following equation for the relative humidities of 20 and 40%.

$$\text{Unit adsorption capacity} = \frac{U}{W} G$$

Where U = unit weight (grams)
W = original weight or sample taken (grams)
G = grain in weight of samples (grams)

CHAPTER 8
TEST PROCEDURE FOR DETERMINING THE MOISTURE ADSORPTION CAPACITY FOR MIL-D-3716 DESICCANT

8.1 FORMULA FOR CALCULATION.

Use Paragraph 7.1 through Paragraph 7.3. Moisture adsorption capacity,

$$\text{percent} = 100x \frac{\begin{array}{l}\text{(final weight of adsorption bulb)}\\ -\text{(original weight of bulb \& sample)}\end{array}}{\begin{array}{l}\text{(original weight of bulb \& sample)}\\ -\text{(weight of empty bulb)}\end{array}}$$

Table 8-1. Minimum Water Vapor Adsorption Capacity (MIL-D-3716)

Nominal Relative Humidity (Percent)	Types I, II and III, Grade H	Type IV, Grade H	Types I, II, III and IV, Grade L
10	5.7	5.5	3.3
20	10.5	10.0	5.0
40	21.5	19.0	7.5
60	30.0	28.0	11.7
80	33.0	33.0	15.0